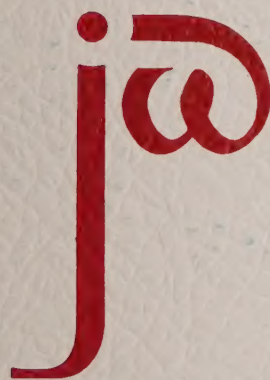
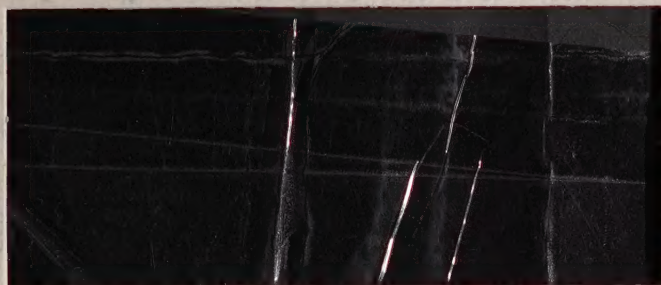
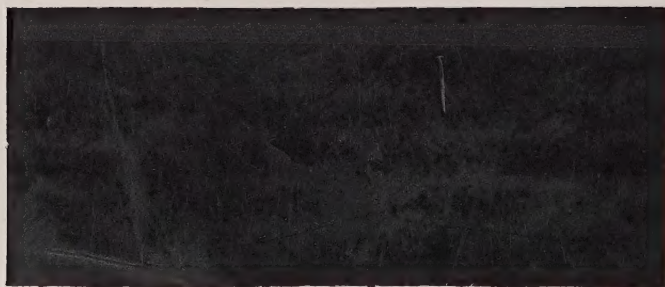


CH 16307  
- RETURN TO -  
INSTRUMENT CONTROL  
SYLVANIA SES -- West

# INSTRUCTION MANUAL



J-OMEGA COMPANY



ID No.  
**CH 16307**  
- RETURN TO -  
INSTRUMENT CONTROL  
SYLVANIA SES -- West

**TYPE 200A SERIES  
VOLT-OHMMETER**

**SERIAL NO. 623**

**CONTENTS**

|                                            |          |
|--------------------------------------------|----------|
| PRODUCT BULLETIN WITH SPECIFICATIONS ..... | ii       |
| INTRODUCTION.....                          | 1        |
| INSTRUMENT WARRANTY.....                   | 2        |
| OPERATING INSTRUCTIONS.....                | 3        |
| THEORY OF OPERATION.....                   | 6        |
| MAINTENANCE AND REPAIR.....                | 9        |
| PARTS LOCATION.....                        | 16       |
| PARTS LIST.....                            | 17       |
| PHOTO OF INTERNAL VIEW.....                | 22       |
| CIRCUIT SCHEMATICS.....                    | APPENDIX |

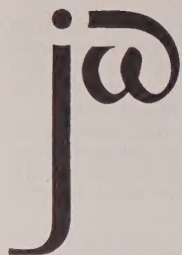


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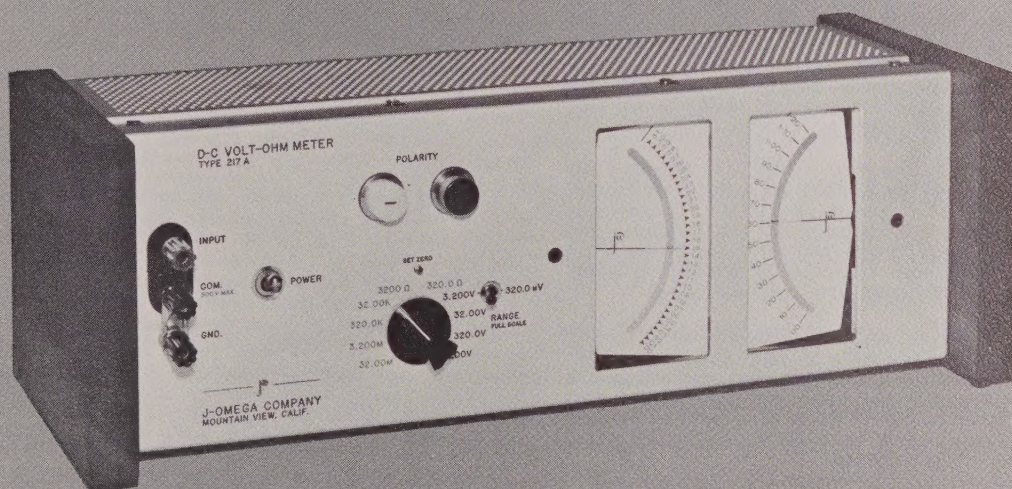






# TYPE 200A SERIES DIGITAL/ANALOG 0.1% DC VOLT-OHMMETER

*For Fast, Precise Measurements*



## USES

**CIRCUIT DESIGN** — Low voltage and resistance scales, high input impedance, AC rejection, fast response fulfill suitability as a very useful design tool.

**PRODUCTION LINE TESTS** — Constant display, digital/analog readout and linear scales contribute to fast, foolproof testing.

**UNATTENDED MONITORING** — Recorder output option permits unattended long-term measurements of both voltage and resistance ranges.

**POWER SUPPLY ADJUSTMENTS AND MONITORING** — Resolution to tenths of a millivolt and visual analog "follow" for observing power supply drift.

**GENERAL LAB INSTRUMENT** — High accuracy and stability combined with unusually broad voltage and resistance ranges.

**HIGH VOLTAGE MEASUREMENTS** — 3200 or 10,000 volt range permits direct use for special applications; 1000 volts floating is standard.

**FIELD TEST UNIT** — No warmup time waiting, compact size and light in weight.

**RECEIVING INSPECTION** — Single control operation, automatic polarity display, isolated input provide desirable measuring speed and versatility.

**SYSTEMS INSTALLATIONS** — Available as a compact, rack mounting unit with input terminals at front or rear.

## FEATURES

**WIDE MEASURING RANGE** — Full-scale ranges from 320 ohms to 32 megohms; 320 millivolts to 3200 volts.

**AUTOMATIC OPERATION** — No balancing operation as with potentiometric type instruments; polarity indication is automatic also.

**OVERLOAD PROTECTION** — Application of maximum kilovolt rating in any voltage range setting will not damage instrument.

**HIGH RESOLUTION** — Exceeds .03% of full scale; 0.1 millivolt on the 320 millivolts range or 0.1 ohm on the 320 ohms range.

**10 KILOVOLT VERSION** — Special high voltage unit for direct measurements to 10 kV; provides constant input impedance of 100 megohms.

**FAST READOUT** — All readings made from same close-positioned linear scales; no scale selection is ever necessary.

**CONSTANT DISPLAY** — Magnitude and direction of input changes are seen immediately; no sampling time delay.

**ALL SOLID-STATE** — Field effect transistor input provides high stability and instant warmup.

**UNIQUE RECORDER OUTPUT** — Recorder traces both digital and analog data on strip chart; provides all four digits of information.

## DESCRIPTION

Volt-Ohmmeter Types 213A, 215A, 217A and 219A have evolved from the success of the original Digital/Analog 21A introduced by J-Omega in 1961. The new models offer numerous improved operating characteristics and greater versatility. They are for applications where measurement of resistance as well as DC voltage are of interest.

The instruments measure and display about 85 to 95% of an unknown input value in true digital form and indicate any remaining increment as an analog vernier that is immediately responsive to the dynamic characteristics of the input. Users find the combination of digital and analog techniques offers several practical advantages when compared with other instruments of either the straight analog or digital type in that: a single control selects both function and range for any operation; there is no null-balancing procedure; readout is fast and foolproof, since the same pair of linear scales is used for all measurements; a changing input does not produce unreadable digit-hunting common to full-digital instruments; and the J-Omega instruments do not sample the input but instead, measure and display it continuously.

These factors provide exceptional "operating rapport" when using a Type 200 Series instrument because the measuring feel of an analog instrument is retained, coupled with the operating simplicity and readout ease of digital equipment; this becomes quite apparent when making the first few measurements with an instrument. These unique instruments are general purpose, broad-range volt-ohmmeters combining the accuracy of a Standards lab instrument with the ruggedness and versatility of an "everyday" multi-range meter. Proper uses include both the engineer's bench and production line where they can be used for routine measurements by semi-skilled persons even when the accuracy capabilities are needed only occasionally. Protection is provided against accidental application of extreme voltages in all voltage range settings.

Two conventional D'Arsonval movements are used, and so arranged that the "resolving power" of one acts to multiply the resolution and accuracy of the other. When an input is applied, the right-hand indicator smoothly moves up the scale until, in the region of full scale, the digital (left) indicator abruptly moves up one step and the right-hand meter drops back to the bottom of its scale. This process is repeated very rapidly until the correct reading is reached within about one second.

The analog meter is calibrated so that the span from 00 to 100 corresponds to 1 step of the digital indicating meter. Since the 00 to 100 span of the interpolating meter is 1/32 of the instrument's range, this results in an improvement of resolution of the D'Arsonval movement by a factor of 32! Movement of the left-hand meter pointer is quantized so that it always points directly to one of 32 numbers (00 through 31) thus providing a true digital indication.

Emphasis was placed on reliability and simplicity in designing these digital/analog instruments. The instruments are transistorized. A field effect transistor input circuit maintains a high and constant input impedance to minimize loading of the source being measured. Particular care has been taken to conservatively select and utilize components well within their ratings as a means to assure trouble-free operation over long periods.

## SPECIFICATIONS

**RANGES** All models have six resistance ranges: 320.0 ohms (20 ma.), 3.200 K (2 ma.), 32.00 K (200  $\mu$ a.), 320.0 K (20  $\mu$ a.), 3.200 M (2  $\mu$ a.), 32.00 M (2  $\mu$ a.)

Specific models have the following plus and minus voltage ranges:

Type 213A: 3.200 V, 32.00 V, 320.0 V, 3200 V

Type 215A: 3.200 V, 32.00 V, 320.0 V, 3200 V, 10 kV

Type 217A: 320.0 mV, 3.200 V, 32.00 V, 320.0 V, 3200 V

Type 219A: 320.0 mV, 3.200 V, 32.00 V, 320.0 V, 3200 V, 10 kV

**ACCURACY**  $\pm 0.1\%$  of full scale or better. (The total accuracy for both resistance and voltage measurements improves linearly from  $\pm 0.1\%$  f.s. at the top of each range to  $\pm 0.03\%$  of f.s. at bottom of each range, i.e., accuracy of any measurement is  $\pm 0.07\%$  of reading plus  $\pm 0.03\%$  of f.s.)

**INPUT IMPEDANCE** Constant 10 megohms  $\pm 0.2\%$  all models all ranges to 3200 V; plus on 215A and 219A 100 megohms all ranges when using the "X10 Input".

**INPUTS** 3-terminal jack-type posts. Common terminal may be floated  $\pm 1000$  V above case on all models; 215A and 219A have additional floating high voltage connector.

## OPERATION

Operating and reading the instrument is very simple and fast. The single function control is used initially to select the operating mode and range. Measurements are then made automatically, including color-coded pilot light polarity indication. The 217A and 219A have a separate two-position panel switch used to select their 320.0 millivolt range.

For readout, the operator simply reads from left to right, obtaining two figures from the left-hand digital indicator and two additional figures from the right-hand indicator. A typical readout might be 23.13 or 2313. In the "320.0mV" range, this would indicate 231.3mV with a resolution of 0.1 millivolt or better!

The 215A and 219A have an additional high voltage input circuit which serves as a "times 10" multiplier with 100 megohm input impedance for any of the four or five basic full-scale ranges. With the range switch in the "3200V" position, measurements up to 10kV can be made using this input.

When conventional accuracy (1 or 2% of full scale) is required, the instrument may be set to the highest range needed so that range switching is completely avoided. For example, work in transistor circuits might seem to call for frequent use of the 3.2 volt range but the right-hand meter resolves 10 millivolts on the 32 volt range. Thus, a single range will cover the highest voltage to be encountered while offering good accuracy on low voltages.

The recorder output option drives single and dual channel recorders. When used with the latter, the readout of both meters is traced on a single chart; this provides complete 4-digit, unambiguous digital/analog recordings.

## CIRCUITRY

A signal voltage proportional to the input is obtained from an input amplifier. This voltage is applied to a binary digitizing circuit that produces a nearly equal voltage quantized in 32 very accurate steps of 0.2 volt each. The left-hand meter is fed from the quantized voltage so that it moves in discrete steps, forming a digital indicator. The right-hand meter indicates the difference between the signal voltage and the quantized voltage. It thus interpolates between the steps of the first indicator.

Circuitry is comprised of three main sections: (1) an input D-C amplifier with associated range resistors. (2) a six-stage binary digitizing circuit which provides a five bit (0 to 31) digit signal plus one bit of polarity (+ or -) information, and (3) a highly stable regulated power supply.

The input amplifier is a four stage single-loop feedback circuit in which the first and second stages are balanced. The digitizer consists of six similar stages, each composed of a balanced pair of transistors for voltage comparison. A precision resistor network provides digital-to-analog reconversion to produce a quantized voltage approximating the input amplifier's output. The power supply reference voltage, obtained with a precision temperature-compensated Zener diode, has a temperature coefficient of approximately  $\pm 0.001\%/^{\circ}\text{C}$ .

For the resistance ranges of the 213A, etc. the unknown resistance replaces the feedback resistor. A constant current applied to the amplifier input produces negligible input voltage but an output voltage proportional to the unknown resistance. Thus, a linear ohmmeter results, eliminating separate non-linear ohms scales.

**BREAKDOWN PROTECTION** Maximum rated kilovolts may be applied through appropriate input in the 320 mV, 3.2 V, etc. voltage range settings without damage to circuitry or meters.

**DRIFT** First hour after turn-on approx. 10 mV max. on 320 mV or 3.2 V ranges and 0.1% f.s. max. on other ranges; thereafter, one-tenth of above figures max. per day in uniform ambient. Panel zero-adjuster permits immediate correction.

**RESPONSE TIME** Full scale negative to full scale positive approx. 1 second; except on 3.2 V, 320 mV and 32 Meg ranges approx. 2 seconds.

**AC REJECTION** Up to 10% of full scale range setting 60 Hz to 100 kHz; to 100% on the 3.2 V and 320 mV ranges.

**DIMENSIONS** Bench:  $5\frac{3}{4}"$  H  $\times$   $16\frac{1}{2}"$  W  $\times$   $6\frac{3}{4}"$  D. Rack: 5-7/32" H  $\times$  19" W  $\times$  5 1/2" D.

**WEIGHT** Net 9 lbs., shipping 14 lbs.

**POWER** 105 to 125 volts AC, 50 to 1000 Hz, 25 watts.

**PRICES** (Either bench or rack style) Type 213A \$685.00; Type 215A \$775.00; Type 217A \$725.00; Type 219A \$815.00.

**OPTIONS** Rear Jack Inputs \$15.00; Recorder Output \$20.00; 220 V Power N/C.

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**J-Omega COMPANY**

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# INTRODUCTION

This instruction manual covers the use and maintenance of the various models comprising the Digital/Analog Series referenced on the title page. Information about the specifications and performance features provided by a specific model is shown on the product bulletin enclosed in this manual.

All models of J-Omega Digital/Analog instruments combine, in a single unique package, the circuitry and operating features of both digital and analog instruments. Four places of information are provided with an accuracy of 0.1% of full scale or better. The left meter indicates the digitized data, which usually comprises 85% or more of an input's value; the remaining increment is displayed in analog form by the right meter. Operation of the instrument is fully automatic, after the appropriate measuring range is selected. It is significant to note that there is no plus or minus one count error factor to add to the basic accuracy statement of the instrument.

Welcomed protection is provided in measuring voltages where, even the lowest range (320 mV or 3.2 V) will sustain accidental application of overloads to 3.2 kV without damage to the circuitry or meters. Nevertheless, the application and handling of this instrument should be made with the reasonable respect due any precision device. Avoid floating an input voltage above 1000 volts as noted on the instrument's panel. In particular, with resistance measuring models, care should be taken not to apply voltage in the resistance measuring mode; these ranges are marked in red as a precaution.

Due to its unusual features, the Digital/Analog instrument makes a fine general purpose laboratory instrument for the intermittent use common to this type of application. There is no reason, however, why the instrument should not be used as an all day, month-after-month production test unit. It is designed to, and has proven to give reliable extended performance with minimum need for service and calibration in such applications.

# **INSTRUMENT WARRANTY**

J-Omega instruments are covered by a one year warranty, the terms of which are stated below.

## **WARRANTY**

J-Omega instruments, and components thereof, are warranted to be free from defects in materials and workmanship for one year from the date of initial factory shipment.

We, or an authorized representative will fully repair equipment of our manufacture covered by the warranty terms on a no-charge basis, to include both parts and labor.

Applications misuse, abuse of the equipment, or unauthorized repair will void this warranty and our obligation to provide no-charge services. J-Omega Company is not liable for consequential damages.

Prior to returning an instrument to the factory for service, please contact J-Omega Company, either directly or through our representative and indicate the nature of the difficulty being encountered. The problem may be one which can be resolved quickly and easily in the field, thereby eliminating the time loss involved in transportation to and from the factory. Instruments sent to the factory should be shipped prepaid.

When non-warranty repairs are to be made, we will notify you of the estimated charges before proceeding with the work.

# OPERATING INSTRUCTIONS

## Preparation

The bench version of the instrument can be placed on its bottom or, if reading convenience makes it desirable, on its back. When used in the normal position the bottom front feet which are threaded into the end blocks, can be extended about 1-1/4 inches to reduce the viewing angle. Rack mounting models fit the standard 19 inch relay rack scheme. Input connections may be located on the rear depending on whether or not this optional feature was ordered.

Application requirements should dictate the user's selection of appropriate input leads, test prods, clips, etc. Models equipped with the special high voltage (10 kV) input are furnished with the mating cable connector. In making up a cable be sure to use wire with a suitable high voltage rating.

Before plugging the unit to power source, note the required nominal input voltage marked on the rear of the instrument. The standard (115 volts) instrument can be powered from AC sources providing 105 to 125 volts, 50 to 1000 Hz. A 220 volt instrument is suitable for use from 210 to 250 volts, 50 to 1000 Hz.

## Panel Controls

**Meter Zero Setting:** Two mechanical zero adjustments are accessible through holes in the front panel, one next to each meter. The need to make this adjustment should be rare. This zeroing should only be done when the power has been off for several minutes or more. Set each meter pointer exactly on the "zero" marker line using the mirror-back feature of the meter to avoid parallax error.

**"POWER" Switch:** The instrument is turned on by moving the lever up. Before doing so it is advisable to make sure that both meters are properly mechanically "zeroed". There is no warmup time waiting required before making measurements, however, at turn-on it is best to check the electrical "zero" before proceeding to make measurements.

**"SET ZERO" Control:** After turn-on this control should be rotated so that both meters are zeroed electrically. This should be done only on the lowest (3.2 volt or 320 mV) range and with the input terminals shorted (resistances up to 2 or 3 megohms are adequate "shorts"). If only one voltage range is to be used, the instrument may be zeroed on this range.

The electrical zero should be checked occasionally and readjusted as necessary during the first hour or so after turn-on. After this zero drift should become negligible.

**NOTE:** Do not use the "SET ZERO" adjustment to obtain offset, as errors may result. In particular, for those models designed to measure resistance, this control should not be used to compensate for ohmmeter lead resistance. Lead resistance when significant, should be measured as a separate step and subtracted from the ohms reading.

**NOTE:** The high resolution of this instrument can be very useful, but the operator should not be misled into making too-frequent or too-exacting adjustment of the "SET ZERO" control. Small errors may be quite visible yet negligible.

**"RANGE" Switch:** Select a range that is at least slightly higher than the highest anticipated input value. In the Type 200 Series this switch permits selection of both ohms ( $\Omega$ , K, M) ranges and volts (V or mV) ranges.

Type 217 and 219 have a two-position toggle switch added to the front panel next to the "RANGE" switch. When the main "RANGE" switch is in its lowest voltage setting, this toggle is used to select between the "3.200V" range and the "320.0mV" range. The selector toggle has no effect when range switching to any of the other voltage and resistance ranges.

**CAUTION:** As is the case with most ohmmeters, resistance measuring models may be damaged by application of excessive voltage to the ohms circuitry. Be sure to use the ohms settings only when testing passive devices.

**Input Terminals:** The "INPUT" (red) terminal is the independent terminal when voltage is measured. It is well insulated against high voltage and leakage. This terminal is positive in resistance measuring models.

The center "COM." terminal connects to the bulk of the internal circuitry and has somewhat lower insulation to the ground. Whenever possible it should be grounded to the "GND." terminal, which is connected to the case and panel. If the common terminal is to be floated from case ground, it is important that the potential between these two terminals not exceed the floating "MAX" noted on the panel.

The upper two terminals of the instrument are used for both voltage and resistance measurement. For voltage measurements, a "+" polarity indication means that the top terminal is positive with respect to the center terminal. The input impedance is a constant 10 megohms ( $\pm 2\%$ ).

**"VOLTS X 10" Input:** Some models are provided with additional capabilities to measure up to 10 kV, with a higher input impedance, by means of using this special high voltage input which supplements the red "INPUT" terminal.

The "VOLTS X 10" input multiplies the range of any of the main voltage ranges by a factor of 10 and provides 100 megohm input impedance for these ranges. The "320.0V" range may then be used to measure up to  $\pm 3,200$  volts; however, the "3200V" range should not be used with inputs higher than  $\pm 10,000$  volts, as is noted on the front panel of the instrument.

Inputs utilizing this connector may be floated to the "MAX" voltage specified for the "COM" terminal that is,  $\pm 1000$  volts by disconnecting the link between the two black input terminals.

**"POLARITY" Lights:** These are in the form of pilot lights marked "+" and "-". They serve to indicate when the instrument is turned on as well as to indicate the polarity of a DC input. An indication of either "+" or "-" may be obtained when the input is zero.

## Measurement Readout

Read left to right four (4) digits, two from each meter to obtain four places of information. Place the decimal as it is located in the range setting. If the right-hand meter reads 1-00 or above, the "1-" alone should be added (transferred) to the reading of the left-hand meter.

Examples: A reading of 27 and 1-03 is read as 2803

A reading of 08 and 65 is read as 0865; on the "32.00V" range of the instrument this would indicate 08.65 V. (By retaining the first 0, the decimal is easily placed after the second figure just as it occurs in the range setting.)

When using the "VOLTS X 10" input, shift location of the decimal point one place to the right for all voltage measurements.

NOTE: In the measurement process the right-hand meter does not scale to 1-20. Normally, the high-scale "switch-point" is in the vicinity of 1-02 to 1-08 after which the pointer resets down exactly 100 (i.e., 02 to 08) as the input value continues to increase. Also, in resistance measuring models it is normal for open inputs to cause the right-hand meter to go off scale on resistance range settings.

## Recorder Output (optional)

Two pairs of terminals are provided on the rear of the instrument to drive a dual pen (overlapping) or dual channel potentiometric recorder. Dual traces will provide records of the instrument's complete four-place readout. The digital meter's output gives the most significant numbers traced on an appropriate chart as distinct digital indications of: 1, 2, 3 or 4, etc.....up to 31. The analog trace shows two additional digits of information in analog form thereby recording, as an expanded scale, the minute changes of the input. Readout can be made anywhere along the chart by noting the digital and analog indications, just as when reading the meters visually.

A single channel recorder can be used to monitor only the analog meter's output. Even then, the value of the now unrecorded digital indication can be determined at any point along the chart. Simply jot down the digital readout when starting to record; later note the direction of (up-scale or down-scale) the analog meter's "resets" and thereupon add or subtract a "one" to the original digital reading for each reset traced up to the area of interest on the chart.

Outputs of the instrument are scaled for use with a 10 mV recorder span (10 mV full scale). Inputs should be isolated (floating) and have an impedance of 1 K or more. To directly read the range in which the analog meter operates without recalibrating the recorder, the chart paper should be graduated from 0 to 120. The recorder channel fed by the digital meter will track between 0 and 31 on the same chart. Charts graduated to at least 110 and somewhat higher than 120 may also be directly read by recalibrating the recorder's span.

Use the adapter cable supplied for hookup. The digital and analog outputs are terminated with connectors marked "D" and "A". Plugs next to the moulded 3/4" long rib are "negative". The digital meter is installed so that with 2.67mV output to the recorder it reads zero (00). When setting up to record, position the digital pen to read "32" with the voltmeter off or disconnected from the recorder. With voltmeter on, the digital pen and meter readings should coincide. Leads without connectors carry polarity data for a recorder event marker. The green and blue leads will drive a marker solenoid requiring 24-28 VDC. Input resistance of the solenoid coil should be 200 ohms or more. Use the green and white leads for event markers requiring a contact closure. In operation the recorder's event marker will continuously indicate polarity of the input and its changes along the chart margin.

# THEORY OF OPERATION

## Input Amplifier

The input amplifier is a transistor circuit having high gain stability by virtue of a large amount of negative feedback and stable feedback resistors. The amplifier consists of a field-effect transistor, FET 1, and transistors Q1 through Q4. FET 1 forms a "source follower" stage which is biased to obtain low drift with changes in temperature. This stage "transforms" the high input circuit impedance for driving the second stage. The second stage is balanced, consisting of two transistors with a common large emitter resistor. These two transistors are thermally joined to minimize the possibility of drift from thermal effects. The succeeding two stages are single ended.

Gain is controlled by varying the resistance in the feedback path. When the instrument is used as a voltmeter, "RANGE" switch S1 selects one of several paths consisting of stable precision resistors. In instruments that operate as an ohmmeter, these same range resistors are used to furnish a constant input current to the junction of R8 and R10. Feedback then is obtained through the unknown resistor in such a way that the current through the unknown just balances the constant current through the range resistor. The resulting voltage drop across the unknown appears at the output of the amplifier to be measured by the digitizing and readout circuitry.

The input amplifier inverts the polarity of the input. When an appropriate range is selected, the amplifier's gain will be such as to produce an output voltage which will be between -6.4 and +6.4 volts. In the following explanations the term "signal" is the inverted output from the amplifier. Thus, a full-scale input voltage or resistance on any range produces a 6.4 volt signal which is negative when the input voltage is positive and vice versa. For various voltage ranges the amplifier has gains such as -2, -.2, -.02, etc.

## Digitizing And Readout Circuits

The signal voltage from the input amplifier is broken down into 64 steps of 0.2 volt each by successively comparing it to six voltages obtained from a resistor matrix, R105, R106, and R135-R162. The first such comparison is with a "0" voltage obtained from R105 and R106. This comparison determines the polarity of the input signal by determining whether the output of the input amplifier is above or below 0 volts.

The result of each comparison is a decision of whether or not to actuate a relay which then adds or subtracts to the voltage for all the following comparisons. Thus if the first comparison detects a negative signal voltage (corresponding to a positive input) relays K101 and K102 are actuated and resistors R157-R159 produce a voltage of -3.2 volts for the next comparison. If the signal voltage had been positive, this second comparison voltage would instead be +3.2 volts.

Similarly, the result of the second comparison determines the position of another relay, K103, which adds or subtracts an additional 1.6 volts to produce a third comparison voltage ( $\pm 3.2$ ,  $\pm 1.6$  volts) from resistors R153-R156. This process is repeated until, after six such comparisons, the signal voltage from the input amplifier is determined within 0.2 volt.

The resulting positions of the relays express the binary numbers from 000000 through 111111. The numbers 100000 to 111111 correspond to inputs of one polarity, while the numbers 000000 to 011111 correspond to inputs of the opposite polarity. The first of these digits, 0 or 1, is displayed as polarity information by the pilot lights. The remaining 32 numbers from 000000 to 111111 are displayed as 32 discrete positions of the left-hand meter. This is done by

connecting weighting resistors to the relay contacts so that each relay contributes to the deflection of meter M102 according to that relay's binary value. Resistors R135-R141 and R160-R163 are used for this function also.

Another set of weighting resistors, R109 and R127-R132 produces a similar quantized voltage for comparison with the signal from the input amplifier. Meter M101 is connected to read the difference between this quantized voltage and the signal voltage from the input amplifier. It thus provides an indication of the difference between the signal voltage and the value indicated by the step-wise meter, M102. It follows that the sum of the meter readings is proportional to the input voltage or resistance.

An understanding of the comparison circuits can be had by considering one of these six circuits separately. We may consider Q116-Q118, R124 and R125, which together form the comparison circuit that drives relay K107. A nearly-constant current of 1 ma is fed to the emitters of Q116 and Q117. Only one of these transistors will conduct, the one which has the more negative base voltage. But the base voltage of Q117 is the signal from the input amplifier while the base voltage of Q116 is a comparison voltage obtained from R135-R141. Thus Q117 will conduct only if the signal voltage is below the comparison voltage, otherwise Q116 will conduct. When Q117 conducts it drives Q118 into conduction and this in turn causes relay K107 to operate.

As an example, the events which take place in measuring a positive input to the instrument that produces -5.5 volts signal to the digitizing and readout circuitry are as follows:

The positive input (which might be +275 V with the "320V" range for example) is inverted by the amplifier so that -5.5 volts appears at the base of the right-hand transistor of each comparator pair.

Decision 1, -5.5 V at the base of Q102 is below "0" volts at Q101 therefore K102 is energized; providing -6.4 volts that is divided to -3.2 volts in resistors R157, 8, 9 for the succeeding comparator; the red (plus) lamp lights and proper polarization is provided to meters by energizing K101. This relay action also contributes -3.2 V to the third comparator's reference through R155, to the fourth comparator through R150, etc.

Decision 2, -5.5 V at Q105 is lower than -3.2 V at Q104 so K103 is energized; -1.6 V is contributed to remaining comparators and the meters.

Decision 3, -5.5 V at Q108 is lower than -4.8 V at Q107 so K104 is energized; -.8 V is contributed to remaining comparators and the meters.

Decision 4, -5.5 V at Q111 is not lower than -5.6 V at Q110 therefore K105 is not energized; +.4 V is contributed to remaining comparators and the meters.

Decision 5, -5.5 V at Q114 is less than -5.2 V (sum of -3.2, -1.6, -.8, +.4) at Q113 so K106 is energized; -.2 V is fed to Q116 and the meters.

Decision 6, -5.5 V at Q117 is lower than -5.4 V therefore K107 is energized contributing -.1 V to the meters.

In addition to the above, R109 contributes a +.1 V offset to M101. (A plus .1 V offset is provided for all negative signal voltages i.e., positive input voltages and vice versa. This is necessary to permit quantized voltages as low as 0.)

Totaling the voltages, we have available to M101:

-3.2 V from K102 through R127  
-1.6 V from K103 through R128  
-0.8 V from K104 through R129  
+0.4 V from K105 through R130  
-0.2 V from K106 through R131  
-0.1 V from K107 through R132  
+0.1 V from R109

Total -5.4 V

M101 presents the difference between this -5.4 V and the -5.5 V signal voltage as a scale indication of 50. M102, the "digital" left-hand meter presents just the -5.4 V quantized signal as a reading of 27. Thus we read 27-50 on the two meters and interpret this, according to the selected range, as an input of 275.0 V, 2.750 V, 2.750 megohms, etc.

### Regulated Power Supply

A zener reference diode, CR205, is in one arm of a bridge consisting also of R217, R218, R220 and R222. R217 is a fixed resistor selected at the factory to set the power supply output to 21.8 volts (measured from -6.4 to +6.4 volt points). The output of the bridge is connected directly to the bases of Q207 and Q208. These balanced transistors amplify the error signal and feed it to Q204 and Q205 which in turn amplify the signal and apply it to Q203, thence to the series transistor Q202 which couples the rectifier output to the regulated +6.4 volt line.

The junction of R219 and R221 is midway between the +6.4 and -6.4 volt lines and, therefore, is used as the "0" volt reference with respect to which all other voltages are measured. Note, however, that this junction has an output impedance of 2000 ohms so that any measurements made from this reference should be made with a high impedance meter; preferably ten megohms or more. Also note that this "0" voltage reference is connected to the center input terminal on the panel only when the range switch is at a VOLTS setting. Thus the center input terminal should not be regarded as an electronic ground for maintenance measurements of the instrument's circuit; instead, find the junction of R219 and R221 and use this as a "0 volts" reference.

An additional regulated power supply is used to supply +50 volts to the comparison circuits and the low-voltage regulator. Here again an error voltage is obtained from a bridge. In this case the 12.8 volt output from the low voltage supply forms one arm of the bridge, the high voltage supply forms another arm and R215 and R216 form the remaining two arms. The bridge output is applied to the base of Q206 which acts as an emitter follower to drive series transistor Q201. Q201 provides variable coupling from the negative output of the rectifier circuit to the +6.4 volt line so that the high voltage supply is effectively in series with the low voltage supply.

Resistor R224 and silicon rectifier CR206 are in series with the negative lead from the low voltage rectifier circuit to provide additional negative voltages of -7.1 and -8.0 volts. These voltages are not critical and are not highly regulated. CR206 is operated only in its forward direction to give a voltage drop of about 0.7 volt; it does not act as a rectifier.

# MAINTENANCE AND REPAIR

## Periodic Maintenance

This type of maintenance is not required other than to provide assurance of the calibration accuracy of the instrument.

It is recommended that a regular check of calibration be performed to provide the user assurance that the calibration is correct. The frequency of such checks will depend upon the level of confidence that is desired. Simple checks against a fixed resistor or standard voltage can be made daily if desired.

Complete calibration might be anything from a monthly to an annual process. In any case, the following procedure is recommended.

## Calibration And Checkout

1. Remove rear cover. Set front-panel mechanical zero adjustments of meters with meter terminals shorted and with power off. It is very important that this be done accurately.
2. Check voltage from -6.4 to +6.4 volt lines (available at R219 and R221); it should be between 12.79 and 12.81 volts. Replace trim resistor R217 with an appropriate value wirewound resistor between 0 and 56 ohms if necessary.
3. Set R160 (600 ohm trimmer, rear board) to calibrate left-hand meter (M102). Using a variable input, set this trimmer so that all 32 meter positions are distinct and unambiguous. To do this it may be necessary to compromise so that pointer is slightly low on some steps and slightly high on others.
4. Using a small input voltage so that the analog meter (M101) reads just about 100, set R108 (50 ohm trimmer, rear board) so that the M101 drops exactly 100 points as M102 steps from 00 to 01. Do not vary the input to obtain the step; short Q118 from base to either collector or emitter to cause the step to occur one way or the other.
5. Check operation of relays. Switching must occur above 00 and below 1-20 as read on M101 when going both up scale and down scale. Normally, the switch-points will be between about 02 and 08 and between 1-02 and 1-08.
6. Check accuracy of resistor set R109 and R127-R132: With instrument carefully zeroed on highest voltage range, cause the polarity indication to reverse by shorting Q103 from base to either emitter or collector. A shift from zero of more than about 1/2 division on the right-hand meter indicates the need for a high-resistance trimming resistor shunting R109 or R127 (depending on direction of shift). Such a resistor should not be lower than about 100 kilohms. Large shifts (several divisions) may indicate need for replacing the set R109 and R127-R132. Before trimming or replacing these resistors make sure that the error is not due to excessive relay contact resistance, especially in K102 and K103.
7. Check for input current. Switch from "3200V" range to "3.200V" range with input open. Right-hand meter should move less than one division.
8. With input shorted, move the range switch from the 3.2 volt position to the 3200 volt position after the instrument has been carefully zeroed. A shift of more than 1/4 division will indicate the need for shunting R219 or R221, depending on the direction of shift. Excessive shift may indicate the need for replacing resistor R219 or R221.

9. Type 200 Series - Calibrate resistance ranges. Use fixed precision resistors near 320 ohms, 3200 ohms, 32 K, etc., as references. Calibration trimmers are on front circuit board as listed. (Note: follow order shown as R21 and R23 will affect all ohms ranges higher than 3200).

| <u>Range</u>   | <u>Trimmers</u>                         |
|----------------|-----------------------------------------|
| 320.0 ohms     | Fixed - replace R20 if necessary        |
| 3200 ohms      | Fixed - replace R21 or R23 if necessary |
| 32.00K (3200V) | Fixed - replace R15 if necessary        |
| 320.0K (320V)  | R18                                     |
| 3200M (32V)    | R17                                     |
| 32.00M (3.2V)  | R16                                     |
| all VOLTS      | R8 (see below)                          |
| 320.0mV        | R46 (see below)                         |

Using an accurate voltage source of 300 or 320 volts, set the "320.0V" range using trimmer R8. Check accuracy of other voltage ranges.

On Types 217 and 219 it is necessary to calibrate the "320.0mV" range as the last step, after R8 has been correctly set. For this step, use a precision input of 300 to 320 mV and trim R46.

If voltage measurements are more important than resistance measurements, it is now permissible to readjust R16-R18 slightly to improve accuracy of voltage readings. It should not be necessary to change these enough to destroy the accuracy of the ohms range.

Type 400 Series - Calibrate voltage ranges. Use a precision voltage source (.01%) having the following voltages: 3000 or 3200 V, 300 or 320 V, 30 or 32 V, 3.0 or 3.2 V and 0.30 or 0.32 V.

Calibration trimmers are on front circuit board as follows:

| <u>Range</u> | <u>Trimmers</u>                            |
|--------------|--------------------------------------------|
| 3200V        | R8 (adjust first as it affects all ranges) |
| 320.0V       | R18                                        |
| 32.00V       | R17                                        |
| 3.200V       | R16                                        |
| 320.0mV      | R36                                        |

10. See page 14 for high voltage calibration of Types 215, 219 and 415.

#### Trouble Shooting

In trouble shooting, the rear circuit board may be removed and laid on the service bench without disconnection. This will make nearly all parts of the instrument highly accessible while the instrument is operating. This may also be done during calibration to make the calibration adjustments more accessible. For trouble shooting it is recommended that a high-impedance voltmeter is used. Preferably 10 megohms or more. (For step 2 above it is permissible to

use an accurate type low-impedance meter.)

NOTE: The center input terminal ("COM") is connected to the "0" volt reference only on VOLTS ranges. When trouble shooting, clip on to the junction of R219 and R221 to obtain the "0" volt reference; do not use the center input terminal.

Probably the most common cause of failure is a shorted transistor, Q<sup>4</sup>, caused by applying an excessive input voltage when the range switch of resistance measuring models is set to a low ohms range. When Q<sup>4</sup> is shorted, the instrument continually reads off-scale positive. Q<sup>4</sup> has been provided with a socket for easy testing and replacement. Further damage may occur if the input voltage is very high or if high input current is available, but this is more rare. Other components subject to damage include Q101 through Q118 and the range resistor involved (such as R21 and R15).

The following transistors are matched pairs and should be replaced as pairs. Pairs are available from J-Omega Company:

Q1 and Q2 (joined)  
Q101 and Q102  
Q104 and Q105  
Q107 and Q108  
Q110 and Q111  
Q113 and Q114  
Q116 and Q117  
Q207 and Q208 (joined)

Any of these pairs may be replaced independently of the other pairs.

Transistor pairs are matched for equal ( $\pm 2$  mV) base-emitter voltage at 1/2 ma collector current, at equal temperatures. Transistors are selected for  $h_{FE}$  of 100 or greater.

Relay covers may be removed for contact cleaning and adjustment. Cleaning should be considered whenever erratic readings are obtained. Starting with relay K102, the lowest numbered relays carry the most current for the resistor matrix and are therefore most subject to contact voltage drop. Paralleled pairs of contacts drive the resistor matrix, although for simplicity they are shown as single contacts on the schematic diagram.

#### Relay Cleaning And Adjustments

IMPORTANT NOTE: The need to adjust relays should be rare. The relays are carefully adjusted at the factory and are designed to operate millions of times (years) without further adjustment. If relay problems are suspected, clean contacts first, then check to see if they operate as described below; adjust only if necessary.

Relay contacts should be bright and clean. Use clean lint-free paper to polish surfaces so as not to remove the gold plating. Do not use a burnishing tool or sandpaper as this will expose the underlying silver and permit tarnishing.

K101 and K102 - Contact sequencing described here is important for K102. To provide interchangeability K101 should also be sequenced. It is not practical to recommend exact gap measurements since mechanical tolerances cause individual relays to differ somewhat; therefore, it will depend upon the good judgment of the technician to determine the correct gaps. When adjusting gaps, bend only the stiffeners, never the contact spring leaves.

With the cover removed, insert a small screwdriver between the plastic base and the horizontal tab of the armature. A levering action on the screwdriver will operate the armature to open and close the contacts while making adjust-

ments. Start with the set of contacts connected to Pins 14 and 16. This set is in the meter circuit and must "break" before the other three sets and also "make" last. By slightly bending the stiffener tabs, spread the contacts until there is definite but very small movement of the outside leaves when the moving contact is operated back and forth.

Now adjust the remaining three sets, with slightly smaller but equal gaps, keeping in mind that they should work in unison. It is extremely important that, though these gaps are not as great as those of the meter relay contacts, they must be adjusted so that all contacts of one set can never touch at the same time; otherwise bridging may occur which will short the power supply and may cause contacts to weld.

K103 through K107 - These relays have two sets of contacts which are connected in parallel for reliability. The object is to adjust both contact sets so they operate in unison, while making the gaps as large as possible.

Actuate the armature only as described above to open the normally closed pairs. Adjust gaps so the four outside contacts move definitely but only slightly.

### Symptoms Of Malfunction

The following list of possible troubles should be of considerable help to the service technician in efforts to repair an instrument. Before attempting repairs, however, study the section, "THEORY OF OPERATION". A thorough understanding of how the instrument works is valuable in tracking down and correcting faults.

#### Symptom

#### Probable Fault And Cause

### I n p u t   A m p l i f i e r

- |                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                     |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. Instrument reads full scale positive at all times.                                                                                                                       | Q4 shorted - replace. Usually due to application of high input voltage when resistance measuring model is set to an ohms range. Also may occur when input is "floated" more than 1000 volts off ground.                                                                                                                                                                                                             |
| 2. Instrument drifts at a steady rate toward + or - full scale. Drift may change or reverse when "SET ZERO" adjuster is turned. May happen on one range only or all ranges. | <p>A. Feedback circuit shorted to ground. Check for shorts between range resistors and "0" volts line or to case. Also check for short in shielded wire to FET socket. Check for points where wire insulation may be pierced. Also check C2 for short circuit.</p> <p>B. Feedback circuit open. Check for continuity from Q4 collector through range resistor, range switch, resistor R10, to FET plug-in unit.</p> |
| 3. Sensitivity very low or zero. May drift erratically.                                                                                                                     | Polystyrene capacitor shorted or leaky (C3 or C11). Capacitor may have been over-voltaged (see 1 above) or mechanically damaged as with a soldering iron. Replace only with polystyrene.                                                                                                                                                                                                                            |

### D i g i t i z i n g   &   R e a d o u t   C i r c u i t s

- |                                                                                                                                            |                                                                                                                                                                                                       |
|--------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 4. Analog meter (M101) goes off scale before switching occurs <u>on some steps only</u> ; OK on other steps. No steps are actually missed. | One or more comparators and relay drivers defective. Use Table I to pinpoint which comparator-relay system is at fault. Matched pairs of transistors may be unbalanced due to overload (see 1 above). |
|--------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

5. As above, but some steps are completely skipped.

Follow 4 above but look for inoperative relay or shorted or open relay driver transistor. If transistor is defective, also check the diode that shunts the relay coil.
6. Analog meter goes off scale in one direction or the other before switching occurs on all steps.

$\pm 6.4$  volt supply may be unregulated due to defective component, especially Q202.  $\pm 6.4$  volt supply may be oscillating due to defective capacitor, especially C201 or C203.  $\pm 50$  V supply may not be regulating, giving excessive voltage. This voltage should be about 48 to 56 V measured from "0" volts line. Check Q201 for possible short.
7. Analog meter moves slightly when power is turned on. Instrument is otherwise completely dead. Fuse is OK.

Power supply shorted from  $+6.4$  V to  $-6.4$  V points. Relay contacts may be welded lightly. Try to determine which relay before removing from socket as handling may clear the short. Replace relay or re-adjust contacts for wider gaps (see instruction on relay adjustment). Also check for other possible short circuits.
8. 320 ohms range inaccurate (reads low) near full scale but accurate over remainder of range.

Q4 has too much saturation resistance. Defective transistor or incorrect type installed.
9. Either meter sticky or digital meter (M102 fails to index properly at one or two points only).

Dirt or lint in meter movement. These are taut-band movements and have no pivots but are still subject to foreign particles.
10. Digital meter does not index correctly on many points.

A. Mechanical zero adjustment of movement may be off. Turn off instrument and short meter terminals or wait 10 minutes. Then adjust movement to line above 31 with extreme accuracy.  
B. Power supply not regulating. Check for 12.8 V  $\pm .01$  V between  $+6.4$  V and  $-6.4$  V lines.  
C. R160 incorrectly adjusted or has developed contact resistance. Rock rotor back and forth 10 times to clean contact surfaces, then adjust according to calibration step 3.
11. Analog meter does not drop or rise exactly 100 points when stepping occurs. This occurs equally on all steps.

See 10B and 10C above except adjust R108 according to calibration step 4.
12. Analog meter drops and rises more or less than 100 points on some steps only (or on all steps alternating from over 100 points to under 100 points).

Inaccurate resistor in group R128 through R132. Use Table I to pinpoint the highest numbered resistor that may be involved. Also check contact voltage drop in corresponding relay. Caution: soldering heat may correct a defective resistor, but only temporarily.
13. Instrument does not read 0 correctly in one polarity when carefully zero adjusted in the other polarity.

A. Right-hand (analog) meter not mechanically zeroed. Turn off instrument and short meter terminals or wait 10 minutes then adjust movement to 0 with extreme accuracy.  
B. Refer to calibration step 6.

## Regulated Power Supplies

14. Voltage calibration incorrect equally on all ranges. (Ohms calibration OK if unit has ohms ranges).
- A. Check power supply from +6.4 V to -6.4 V. Should be 12.79 to 12.81 volts. Errors may be due to shifts in CR205, R220, R222 or possibly other components. Before re-trimming, make sure that voltage does not drift with time and temperature. Especially make sure that CR205 voltage remains very constant as unit warms up; this should not drift more than about 2 or 3 mV. Heat a suspected component to see if this causes large power supply changes or drift.
- B. If power supply is OK, re-trim R8 according to calibration step 9.
15. Voltage calibration changes as instrument warms up.
- A. Power supply component changing with temperature. Monitor 12.8 V power supply voltage; it should not drift more than about 5 mV over normal temperature range. See 14A above.
- B. Check Q202 for excessive leakage.
16. Voltage calibration fails after unit warms up, especially at high line voltages.
- Check Q202 for excessive leakage. Also monitor for possible power supply oscillation due to internal defect in C201.
17. Relays buzz severely near switching points (Note: A very slight buzzing sometimes occurs and is normal).
- A. Power supply producing excessive hum and ripple, especially +50 V supply. Q201 may be defective. (Note: +50 V supply will "follow" the 12.8 V supply and will duplicate its hum and drift, therefore, first test the 12.8 V supply from +6.4 V to -6.4 V points; hum, ripple and noise on 12.8 V supply should be about 1 mV or less, and about 25 mV or less for +50 V supply).
- B. Power supply oscillating. Probably due to defective capacitor.
- 

(continued from page 10)

Since the 90 meg resistor in Types 215, 219 and 415 is not adjustable, it is necessary to adjust the instrument's power supply to assure correct calibration of the "Volts X 10" Input. After completing the calibration procedure in steps 1 through 9, using the standard input, proceed as follows:

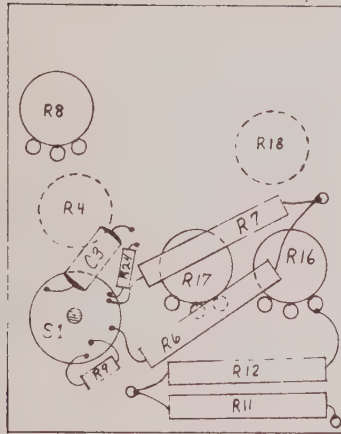
1. Set the range switch to "32.00V" and apply a precision 320 volt source to the "Volts X 10" Input. The instrument should read just 32.00 volts X 10. If a small error exists, readjust the power supply voltage by a slight change of trim resistor R217.
2. If it was necessary to readjust the power supply voltage in the above step, the standard input will now need readjustment. Apply a precision 32 volt source to the standard (X1) input, still using the "32.00V" range. Set resistor R8 to obtain a reading of just 32.00 volts. (Do not change the setting of range resistor R17).

## Switching Analysis

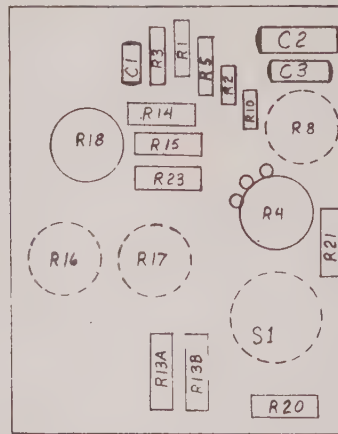
| The Component Groups Below<br>Produce Switching ....               | ... Between These Points<br>(Positive Or Negative)                                                                                                                                  |
|--------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Q116-Q118, K107,<br>R124, R125, R135-R141, R160-R162,<br>CR106     | 0 and 1, 2 and 3, 4 and 5,<br>6 and 7, 8 and 9, 10 and 11,<br>12 and 13, 14 and 15, 16 and 17,<br>18 and 19, 20 and 21, 22 and 23,<br>24 and 25, 26 and 27, 28 and 29,<br>30 and 31 |
| Q113-Q115, K106<br>R121, R122, R142-R147<br>CR105                  | 1 and 2, 5 and 6, 9 and 10,<br>13 and 14, 17 and 18, 21 and 22,<br>25 and 26, 29 and 30                                                                                             |
| Q110-Q112, K105<br>R118, R119, R148-R152,<br>CR104                 | 3 and 4, 11 and 12, 19 and 20,<br>27 and 28,                                                                                                                                        |
| Q107-Q109, K104,<br>R115, R116, R153-R156,<br>CR103                | 7 and 8, 23 and 24                                                                                                                                                                  |
| Q104-Q106, K103,<br>R112, R113, R157-R159,<br>CR102                | 15 and 16                                                                                                                                                                           |
| Q101-Q103, K101, K102,<br>R104-R107, R110, R111,<br>C101,<br>CR101 | -0 and +0 (Polarity)                                                                                                                                                                |

Table I

## PARTS LOCATION



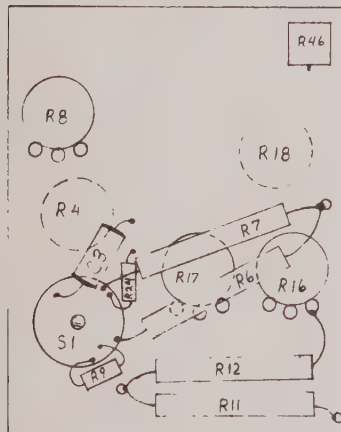
FRONT



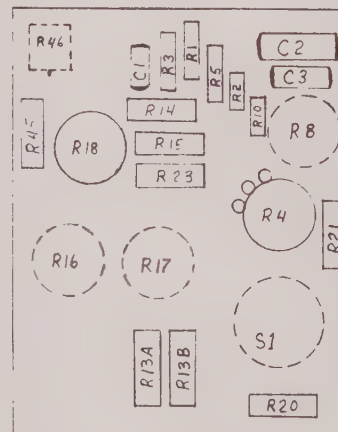
REAR

TYPES 213 &  
215.

PARTS LOCATION  
FRONT CIRCUIT  
BOARD.



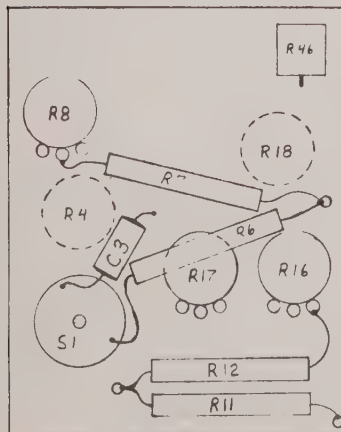
FRONT



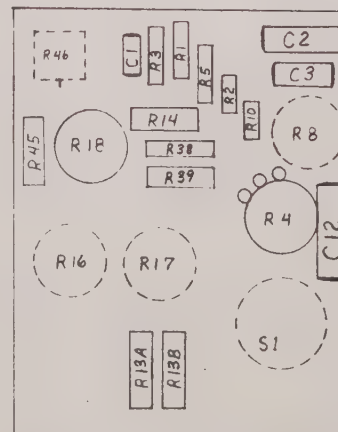
REAR

TYPES 217 &  
219.

PARTS LOCATION  
FRONT CIRCUIT  
BOARD.



FRONT



REAR

TYPES 413 &  
415.

PARTS LOCATION  
FRONT CIRCUIT  
BOARD.

# PARTS LIST

(See Manufacturers Code on last page)

| CAPACITORS         |                                                                       | MFR & P/N                            | QUAN. | RECT & DIODES |                             | MFR & P/N    | QUAN. |
|--------------------|-----------------------------------------------------------------------|--------------------------------------|-------|---------------|-----------------------------|--------------|-------|
| C1                 | .04mf, 100v<br>mylar                                                  | Elmenco<br>1DP-1-403                 | 1     | CR103         | same as CR101               |              |       |
|                    |                                                                       |                                      |       | CR104         | same as CR101               |              |       |
| C2                 | .027mf, 600v<br>mylar-paper                                           | Elmenco<br>6DP-3-273                 | 1     | CR105         | same as CR101               |              |       |
| C3                 | .01mf, 500v<br>polystyrene                                            | Centralab<br>CPR                     | 1     | CR106         | same as CR101               |              |       |
| C4                 | same as C206                                                          |                                      |       | CR201         | 1N3193                      | R.C.A.       | 6     |
|                    |                                                                       |                                      |       | CR202         | same as CR201               |              |       |
| C5                 | .25mf, 100v<br>mylar                                                  | Elmenco<br>1DP-3-254                 | 1     | CR203         | same as CR201               |              |       |
| C6                 | 5pf, 500v<br>mica or<br>polystyrene                                   | Corn.-Dub.<br>or<br>Centralab<br>CPR | 1     | CR204         | same as CR201               |              |       |
|                    |                                                                       |                                      |       | CR205         | 1N2166A                     | US Sem Cor   | 1     |
|                    |                                                                       |                                      |       | CR206         | same as CR201               |              |       |
| C11                | 1000pf, 500v<br>polystyrene<br>(in Types 217,<br>219, 413 and<br>415) | Centralab<br>CPR                     | 1     | CR207         | same as CR201               |              |       |
| <u>TRANSISTORS</u> |                                                                       |                                      |       |               |                             |              |       |
|                    |                                                                       |                                      |       | Q1            | matched pair                | J-0          | 2     |
| C101               | 25mf, 6v<br>electrolytic                                              | J-0<br>P5050                         | 1     | Q2            | 2N404                       | P3025        |       |
| C201               | 900mf, 35v<br>electrolytic                                            | J-0<br>P5017                         | 1     | Q3            | 2N1309 or<br>selected 2N404 | J-0<br>P3021 | 1     |
| C202               | 2.2mf, 3v<br>ceramic disc                                             | Sprague<br>HY150                     | 2     | Q4            | 2N3415                      | G.E.         | 9     |
|                    |                                                                       |                                      |       | Q101          | matched pair                | J-0          | 6     |
| C203               | 150mf, 15v<br>electrolytic                                            | J-0<br>P5042                         | 1     | Q102          | 2N404                       | P3024        |       |
| C204               | 20mf, 100v<br>electrolytic                                            | J-0<br>P5044                         | 1     | Q103          | same as Q4                  |              |       |
|                    |                                                                       |                                      |       | Q104          |                             |              |       |
| C205               | same as C202                                                          |                                      |       |               | same as Q101,102            |              |       |
|                    |                                                                       |                                      |       | Q105          |                             |              |       |
| C206               | .1mf, 100v<br>mylar                                                   | Elmenco<br>1DP-2-104                 | 2     | Q106          | same as Q103                |              |       |
|                    |                                                                       |                                      |       | Q107          |                             |              |       |
|                    |                                                                       |                                      |       |               | same as Q101,102            |              |       |
| CR1                | 1N34A<br>or similar                                                   | General<br>Instrument                | 1     | Q108          |                             |              |       |
|                    |                                                                       |                                      |       | Q109          | same as Q103                |              |       |
| CR101              | 1N461                                                                 | Continental                          | 6     | Q110          |                             |              |       |
|                    |                                                                       |                                      |       |               | same as Q101,102            |              |       |
| CR102              | same as CR101                                                         |                                      |       | Q111          |                             |              |       |
| C207               | .01mf, 50v,<br>ceramic disc                                           | Sprague<br>TG 310                    | 2     |               |                             |              |       |
| C208               |                                                                       |                                      |       |               |                             |              |       |

| <u>TRANSISTORS</u> |                                            |              | <u>MFR &amp; P/N</u> | <u>QUAN.</u> | <u>RESISTORS</u> |                                                                                      |  | <u>MFR &amp; P/N</u> | <u>QUAN.</u> |
|--------------------|--------------------------------------------|--------------|----------------------|--------------|------------------|--------------------------------------------------------------------------------------|--|----------------------|--------------|
| Q112               | same as Q103                               |              |                      |              | R10              | composition,<br>4.7M, $\frac{1}{2}w$ , 10%                                           |  | A-B                  | 1            |
| Q113               |                                            |              |                      |              | R11              | metal film,<br>9.9M, 2w, 1%                                                          |  | J-O<br>P4033         | 2            |
| Q114               | same as Q101,102                           |              |                      |              | R12              | same as R11                                                                          |  |                      |              |
| Q115               | same as Q103                               |              |                      |              | R13A             | film type,<br>475K, $\frac{1}{2}w$ , 1%                                              |  | IRC Type<br>MEC - T2 | 1            |
| Q116               | same as Q101,102                           |              |                      |              | R13B             | film type,<br>1.5M, $\frac{1}{2}w$ , 1%                                              |  | IRC Type<br>MEC - T2 | 1            |
| Q117               |                                            |              |                      |              |                  |                                                                                      |  |                      |              |
| Q118               | same as Q103                               |              |                      |              | R14              | metal film,<br>196K, $\frac{1}{2}w$ , 1%                                             |  | J-O<br>P4035         | 1            |
| Q201               | 2N1183                                     | R.C.A.       | 1                    |              | R15              | wirewound,<br>18K, .02% (in<br>Types 213, 215,<br>217 and 219)                       |  | J-O<br>P4053         | 1            |
| Q202               | 2N3613                                     | Motorola     | 1                    |              | R16              | variable, 500K<br>composition                                                        |  | J-O<br>P4043         | 1            |
| Q203               | 2N404                                      | Tex. Inst.   | 2                    |              | R17              | variable, 50K<br>composition                                                         |  | J-O<br>P4044         | 1            |
| Q204               | same as Q103                               |              |                      |              | R18              | variable, 5K<br>wirewound                                                            |  | CTS/IRC<br>112-5000  | 1            |
| Q205               | same as Q103                               |              |                      |              |                  |                                                                                      |  |                      |              |
| Q206               | same as Q203                               |              |                      |              | R20              | wirewound, 320<br>ohm, .02% (in<br>Types 213, 215,<br>217 and 219)                   |  | J-O<br>P4061         | 1            |
| Q207               |                                            |              |                      |              | R21              | wirewound,<br>10,666.7 ohm,<br>.02% (in Types<br>213, 215, 217<br>and 219)           |  | J-O<br>P4062         | 1            |
| Q208               | same as Q1,2                               |              |                      |              | R22              | omit                                                                                 |  |                      |              |
| <u>RESISTORS</u>   |                                            |              |                      |              | R23              | wirewound,<br>2,461.54 ohm,<br>.02% (in Types<br>213, 215, 217<br>and 219)           |  | J-O<br>P4063         | 1            |
| R1                 | film type,<br>51.1K, $\frac{1}{2}w$ , 1%   | E            | 1                    |              | R24              | composition,<br>680 ohm, $\frac{1}{2}w$ , 10%<br>(in Types 213,<br>215, 217 and 219) |  | A-B                  | 1            |
| R2                 | composition,<br>22M, $\frac{1}{2}w$ , 10%  | A-B          | 2                    |              | R25              | omit                                                                                 |  |                      |              |
| R2A                | same as R2                                 |              |                      |              | R26              | omit                                                                                 |  |                      |              |
| R3                 | film type,<br>1.33K, $\frac{1}{2}w$ , 1%   | E            | 2                    |              |                  |                                                                                      |  |                      |              |
| R4                 | multi-turn, 50K,<br>composition            | J-O<br>P4047 | 1                    |              |                  |                                                                                      |  |                      |              |
| R5                 | same as R3                                 |              |                      |              |                  |                                                                                      |  |                      |              |
| R6                 | metal film,<br>4.95M, 2w, 1%               | J-O<br>P4032 | 2                    |              |                  |                                                                                      |  |                      |              |
| R7                 | same as R6                                 |              |                      |              |                  |                                                                                      |  |                      |              |
| R8                 | variable,<br>250K, compo-<br>sition        | J-O<br>P4046 | 1                    |              |                  |                                                                                      |  |                      |              |
| R9                 | composition,<br>3.3M, $\frac{1}{2}w$ , 10% | A-B          | 1                    |              |                  |                                                                                      |  |                      |              |

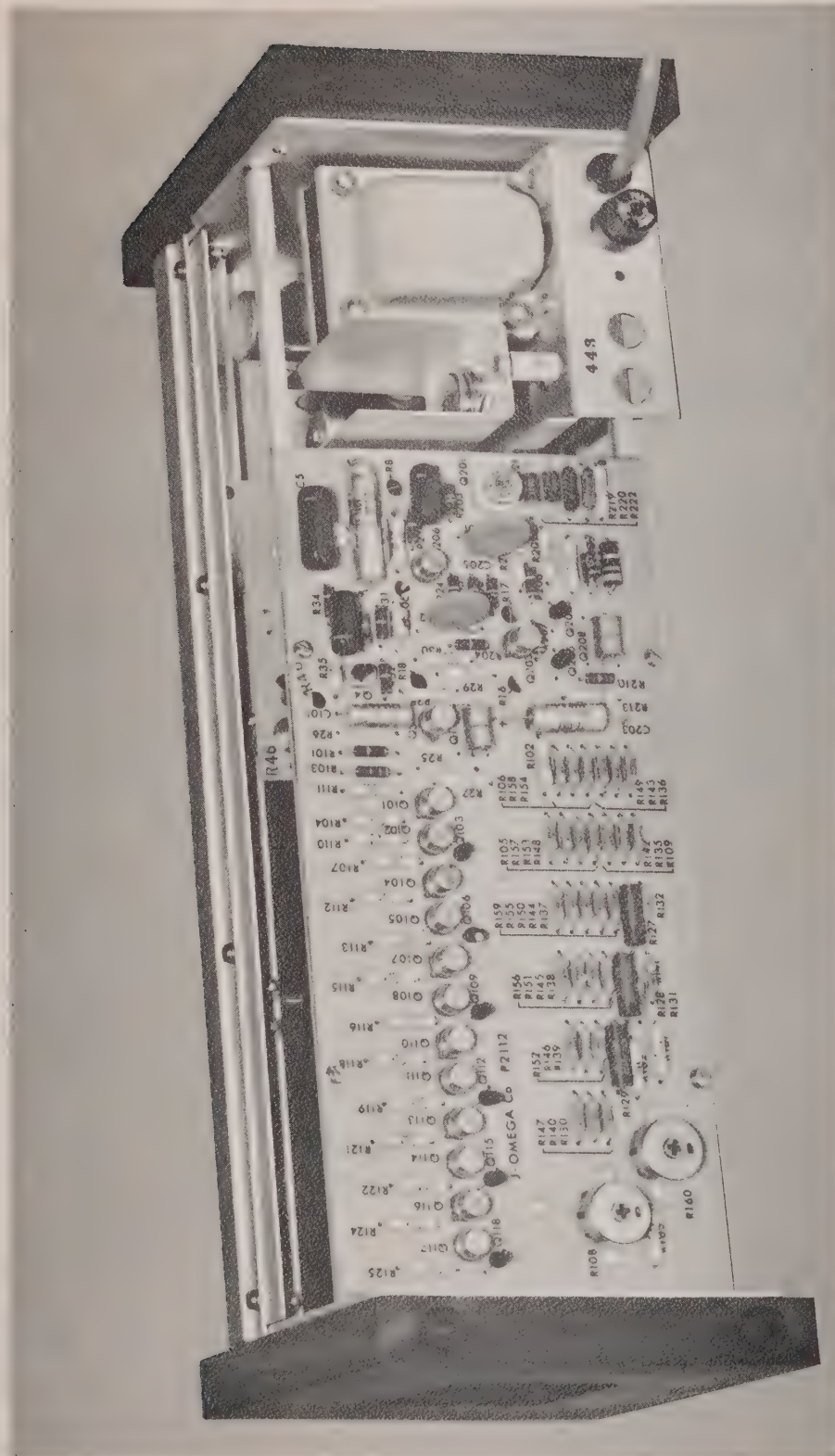
| <u>RESISTORS</u> |                                                                                             |                      |              | <u>RESISTORS</u> |                                            |                      |              |
|------------------|---------------------------------------------------------------------------------------------|----------------------|--------------|------------------|--------------------------------------------|----------------------|--------------|
|                  |                                                                                             | <u>MFR &amp; P/N</u> | <u>QUAN.</u> |                  |                                            | <u>MFR &amp; P/N</u> | <u>QUAN.</u> |
| R27              | film type,<br>12.7K, $\frac{1}{2}$ w, 1%                                                    | E                    | 3            | R103             | composition,<br>6.8K, $\frac{1}{2}$ w, 10% | A-B                  | 1            |
| R28              | film type,<br>31.6K, $\frac{1}{2}$ w, 1%                                                    | E                    | 1            | R104             | film type,<br>51.1K, $\frac{1}{2}$ w, 1%   | E                    | 6            |
| R29              | film type,<br>475 ohm, $\frac{1}{2}$ w, 1%                                                  | E                    | 4            | R105             | film type, 400<br>ohm, 0.1%                | J-0<br>P4070         | 7            |
| R30              | film type,<br>261 ohm, $\frac{1}{2}$ w, 1%                                                  | E                    | 2            | R106             | same as R105                               |                      |              |
| R31              | composition,<br>1.5K, $\frac{1}{2}$ w, 10%                                                  | A-B                  | 4            | R107             | film type,<br>1.50K, $\frac{1}{2}$ w, 1%   | E                    | 6            |
| R32              | same as R31                                                                                 |                      |              | R108             | variable, 50<br>ohm, wirewound             | CTS/IRC<br>112-50    | 1            |
| R33              | composition,<br>100 ohm, $\frac{1}{2}$ w, 10%                                               | A-B                  | 1            | R109             | film type,<br>6.4K, 0.1%                   | J-0<br>P4074         | 6            |
| R34              | composition,<br>10 ohm, $\frac{1}{2}$ w, 10%                                                | A-B                  | 2            | R110             | film type, 100K,<br>$\frac{1}{2}$ w, 1%    | E                    | 1            |
| R35              | same as R27                                                                                 |                      |              | R111             | same as R30                                |                      |              |
| R36              | omit                                                                                        |                      |              | R112             | same as R104                               |                      |              |
| R37              | omit                                                                                        |                      |              | R113             | same as R107                               |                      |              |
| R38              | film type, 2K,<br>$\frac{1}{2}$ w, 1% (in Types<br>413 and 415)                             | E                    | 1            | R115             | same as R104                               |                      |              |
| R39              | wirewound, 20K,<br>.02% (in Types<br>413 and 415)                                           | J-0<br>P4055         | 1            | R116             | same as R107                               |                      |              |
| R45              | metal film,<br>523K, $\frac{1}{2}$ w, 1%,<br>T-2 (in Types<br>217, 219, 413<br>and 415)     | Mepco                | 1            | R118             | same as R104                               |                      |              |
| R46              | variable, 50K,<br>comp. (in Types<br>217, 219, 413<br>and 415)                              | Helipot<br>78PR50K   | 1            | R119             | same as R107                               |                      |              |
| R47              | encapsulated,<br>high voltage<br>resistor, 90M,<br>2w, 1% (in<br>Types 215, 219<br>and 415) | J-0<br>P2102         | 1            | R121             | same as R104                               |                      |              |
| R101             | composition,<br>10 ohm, $\frac{1}{2}$ w, 5%                                                 | A-B                  | 1            | R122             | same as R107                               |                      |              |
| R102             | film type, 100<br>ohm, $\frac{1}{2}$ w, 1%                                                  | E                    | 1            | R124             | same as R104                               |                      |              |
|                  |                                                                                             |                      |              | R125             | same as R107                               |                      |              |
|                  |                                                                                             |                      |              | R127             | wirewound, 200<br>ohm, .02%                | J-0<br>P4064         | 1            |
|                  |                                                                                             |                      |              | R128             | wirewound, 400<br>ohm, .02%                | J-0<br>P4065         | 1            |
|                  |                                                                                             |                      |              | R129             | wirewound, 800<br>ohm, .02%                | J-0<br>P4066         | 1            |
|                  |                                                                                             |                      |              | R130             | film type,<br>1.6K, 0.1%                   | J-0<br>P4072         | 6            |
|                  |                                                                                             |                      |              | R131             | film type,<br>3.2K, 0.1%                   | J-0<br>P4073         | 5            |
|                  |                                                                                             |                      |              | R132             | same as R109                               |                      |              |

| <u>RESISTORS</u> |                                          |                    | <u>MFR &amp; P/N</u> | <u>QUAN.</u> | <u>RESISTORS</u> |                                                  |  | <u>MFR &amp; P/N</u> | <u>QUAN.</u> |
|------------------|------------------------------------------|--------------------|----------------------|--------------|------------------|--------------------------------------------------|--|----------------------|--------------|
| R135             | same as R109                             |                    |                      |              | R201             | composition,<br>33 ohm, $\frac{1}{2}$ w, 10%     |  | A-B                  | 1            |
| R136             | same as R109                             |                    |                      |              | R202             | omit                                             |  |                      |              |
| R137             | film type,<br>213.33 ohm, 0.1%           | J-0<br>P4069       |                      | 1            | R203             | composition,<br>15K, $\frac{1}{2}$ w, 10%        |  | A-B                  | 1            |
| R138             | same as R105                             |                    |                      |              | R204             | same as R34                                      |  |                      |              |
| R139             | film type,<br>800 ohm, 0.1%              | J-0<br>P4071       |                      | 6            | R205             | same as R31                                      |  |                      |              |
| R140             | same as R130                             |                    |                      |              | R206             | composition,<br>4.7K, $\frac{1}{2}$ w, 10%       |  | A-B                  | 2            |
| R141             | same as R131                             |                    |                      |              | R207             | composition,<br>39K, $\frac{1}{2}$ w, 10%        |  | A-B                  | 1            |
| R142             | same as R109                             |                    |                      |              | R208             | composition,<br>2.7 ohm, $\frac{1}{2}$ w, 10%    |  | A-B                  | 1            |
| R143             | same as R109                             |                    |                      |              | R209             | same as R29                                      |  |                      |              |
| R144             | same as R105                             |                    |                      |              | R210             | same as R206                                     |  |                      |              |
| R145             | same as R139                             |                    |                      |              | R211             | film type,<br>931 ohm, $\frac{1}{2}$ w, 1%       |  | E                    | 1            |
| R146             | same as R130                             |                    |                      |              | R212             | same as R29                                      |  |                      |              |
| R147             | same as R131                             |                    |                      |              | R213             | same as R29                                      |  |                      |              |
| R148             | same as R131                             |                    |                      |              | R214             | same as R31                                      |  |                      |              |
| R149             | same as R131                             |                    |                      |              | R215             | same as R27                                      |  |                      |              |
| R150             | same as R105                             |                    |                      |              | R216             | film type,<br>3.48K, $\frac{1}{2}$ w, 1%         |  | E                    | 1            |
| R151             | same as R139                             |                    |                      |              | R217             | stable type,<br>value selected<br>in manufacture |  |                      | 1            |
| R152             | same as R130                             |                    |                      |              | R218             | film type, 316<br>ohm, $\frac{1}{2}$ w, 1%       |  | E                    | 1            |
| R153             | same as R130                             |                    |                      |              | R219             | wirewound,<br>200 ohm, 0.1%                      |  | J-0<br>P4075         | 2            |
| R154             | same as R130                             |                    |                      |              | R220             | wirewound,<br>150 ohm, 1%                        |  | J-0<br>P4080         | 1            |
| R155             | same as R105                             |                    |                      |              | R221             | same as R19                                      |  |                      |              |
| R156             | same as R139                             |                    |                      |              | R222             | wirewound,<br>50 ohm, 1%                         |  | J-0<br>P4081         | 1            |
| R157             | same as R139                             |                    |                      |              | R224             | composition,<br>1 ohm, $\frac{1}{2}$ w, 10%      |  | A-B                  | 2            |
| R158             | same as R139                             |                    |                      |              | R225             | wirewound,<br>50 ohm, 5w, 5%                     |  | Sprague<br>452E      | 1            |
| R159             | same as R105                             |                    |                      |              | R226             | same as R224                                     |  |                      |              |
| R160             | variable, 600<br>ohm, wire-w.            | CTS/IRC<br>112-600 |                      | 1            |                  |                                                  |  |                      |              |
| R161             | film type,<br>6.04K, $\frac{1}{2}$ w, 1% | E                  |                      | 2            |                  |                                                  |  |                      |              |
| R162             | same as R161                             |                    |                      |              |                  |                                                  |  |                      |              |
| R163             | film type,<br>402K, $\frac{1}{2}$ w, 1%  | E                  |                      | 1            |                  |                                                  |  |                      |              |

| OTHER COMPONENTS |                                                    |            |       | OTHER COMPONENTS |                                                     |                        |       |
|------------------|----------------------------------------------------|------------|-------|------------------|-----------------------------------------------------|------------------------|-------|
|                  |                                                    | MFR & P/N  | QUAN. |                  |                                                     | MFR & P/N              | QUAN. |
| F201             | fuse, 3/10 amp, S10-B10 (2/10 amp for 220v models) | Littlefuse | 1     | M101             | meter, analog                                       | J-0 P7101              | 1     |
| I101             | lamp, 14.4v                                        | G.E. 1813  | 2     | M102             | meter, digital                                      | J-0 P7102              | 1     |
| I102             | same as I101                                       |            |       | S1               | switch, ten position, rotary (in Types 213 and 215) | J-0 P7021              | 1     |
| XI101            | pilot light, red (+)                               | J-0 P8030  | 1     |                  | (in Types 217 and 219)                              | J-0 P7026              |       |
| XI102            | pilot light, white (-)                             | J-0 P8031  | 1     |                  | (in Types 413 and 415)                              | J-0 P7027              |       |
| K101             | relay, 4pdt                                        | J-0 P7010  | 2     | S2               | switch, toggle, dpdt (in Types 217 and 219)         | C&K 7201               | 1     |
| K102             | same as K101                                       |            |       | S201             | switch, toggle, spst                                | Cutler-Hammer 8280-K15 | 1     |
| K103             | relay, dpdt                                        | J-0 P7011  | 5     | T201             | transformer, 115v primary                           | J-0 P6111              | 1     |
| K104             | same as K103                                       |            |       |                  | (option) 230v primary                               | J-0 P6112              |       |
| K105             | same as K103                                       |            |       | —                | FET plug-in                                         | J-0 P200 <sup>13</sup> | 1     |
| K106             | same as K103                                       |            |       |                  |                                                     |                        |       |
| K107             | same as K103                                       |            |       |                  |                                                     |                        |       |

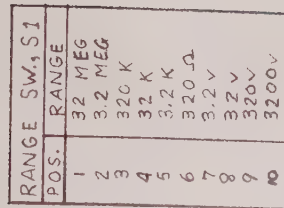
Manufacturers Code:

J-O J-Omega Company  
A-B Allen-Bradley Company; Type EB (resistor)  
E Electra Mfg. Company; Type MF7C (resistor)



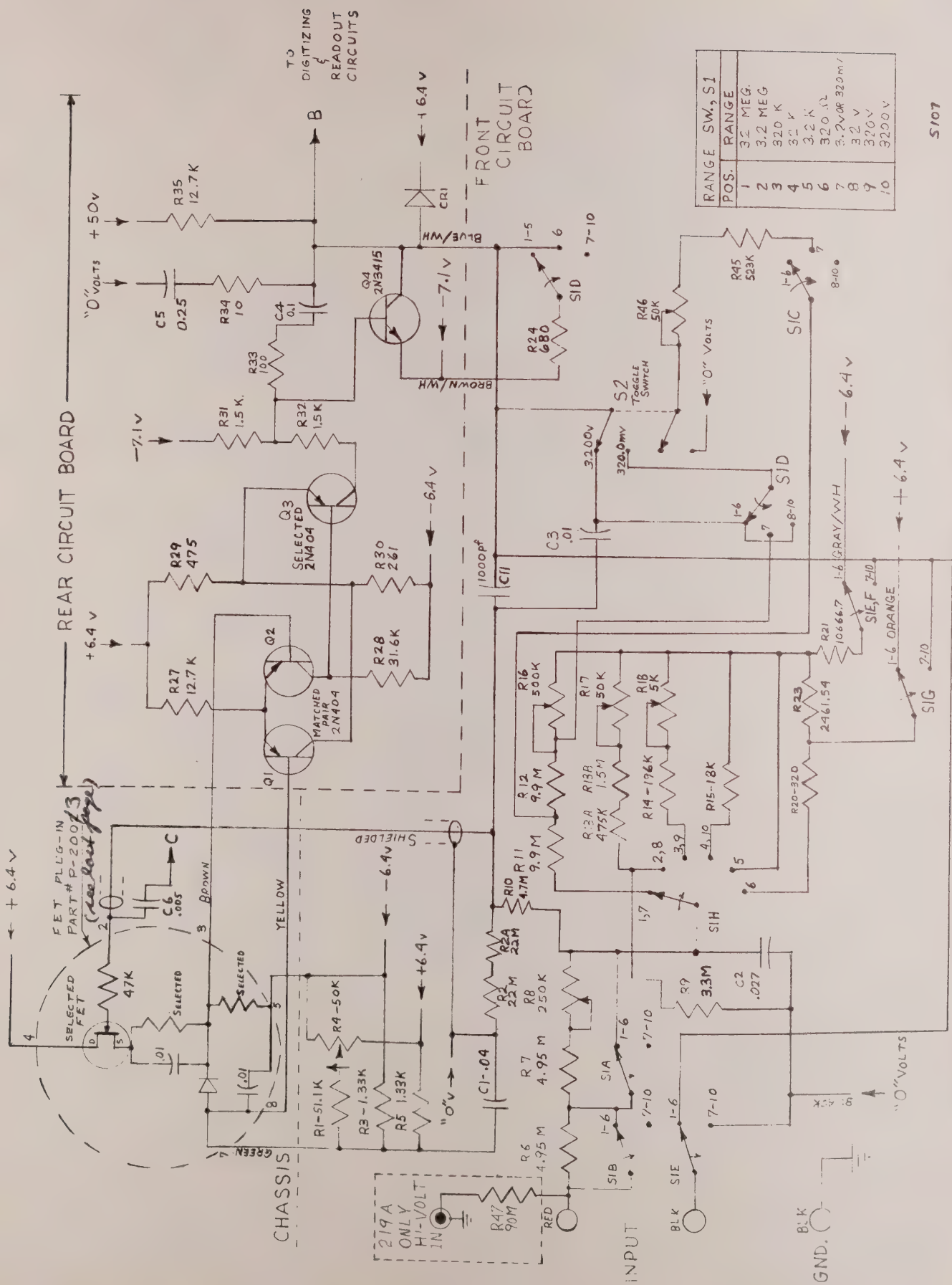
**REAR INTERNAL VIEW**

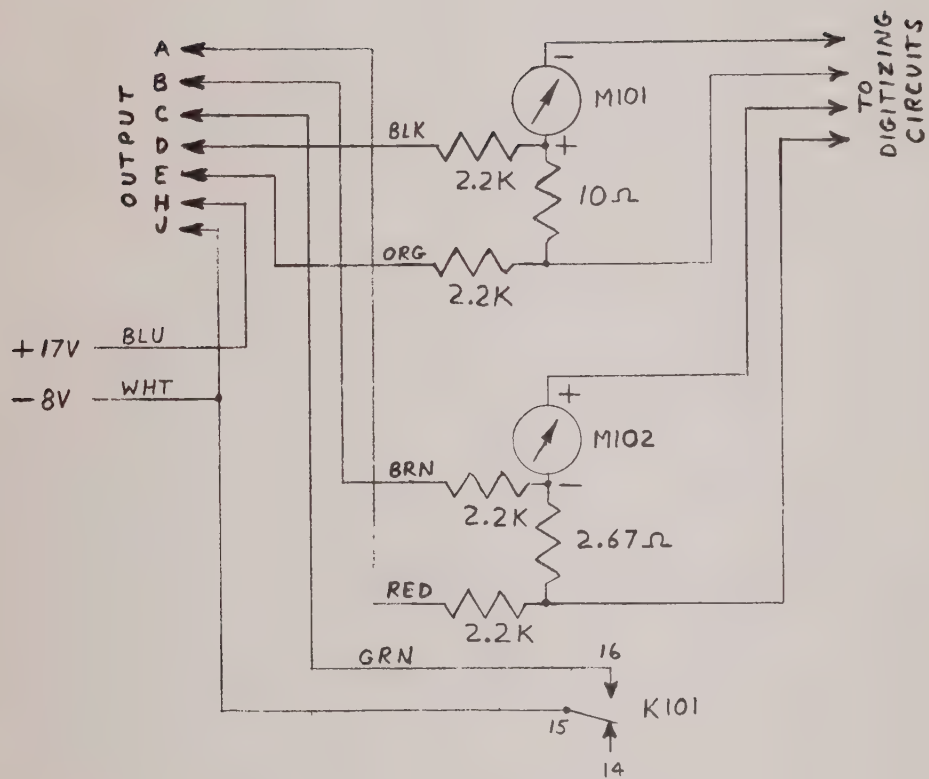
5107





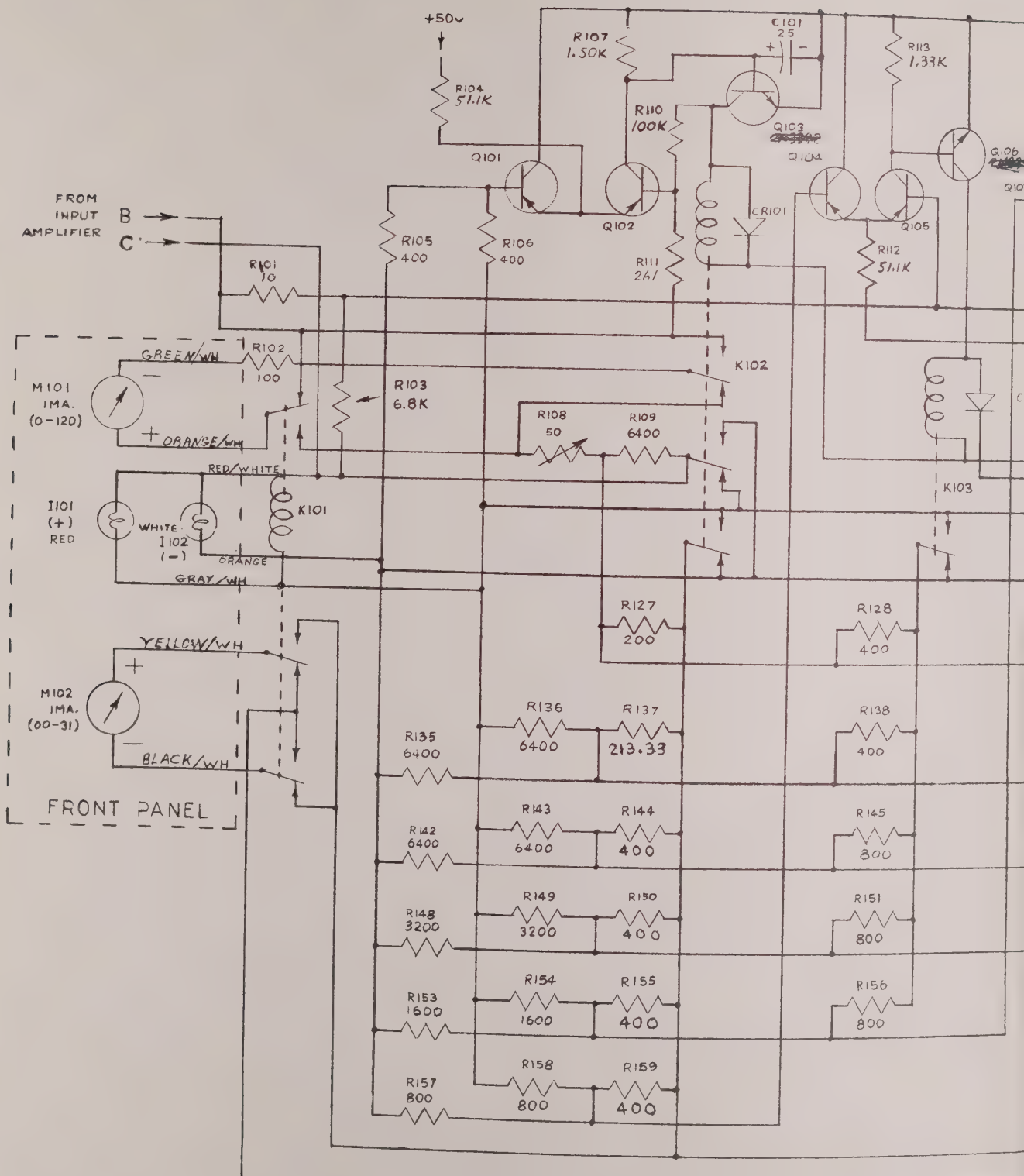
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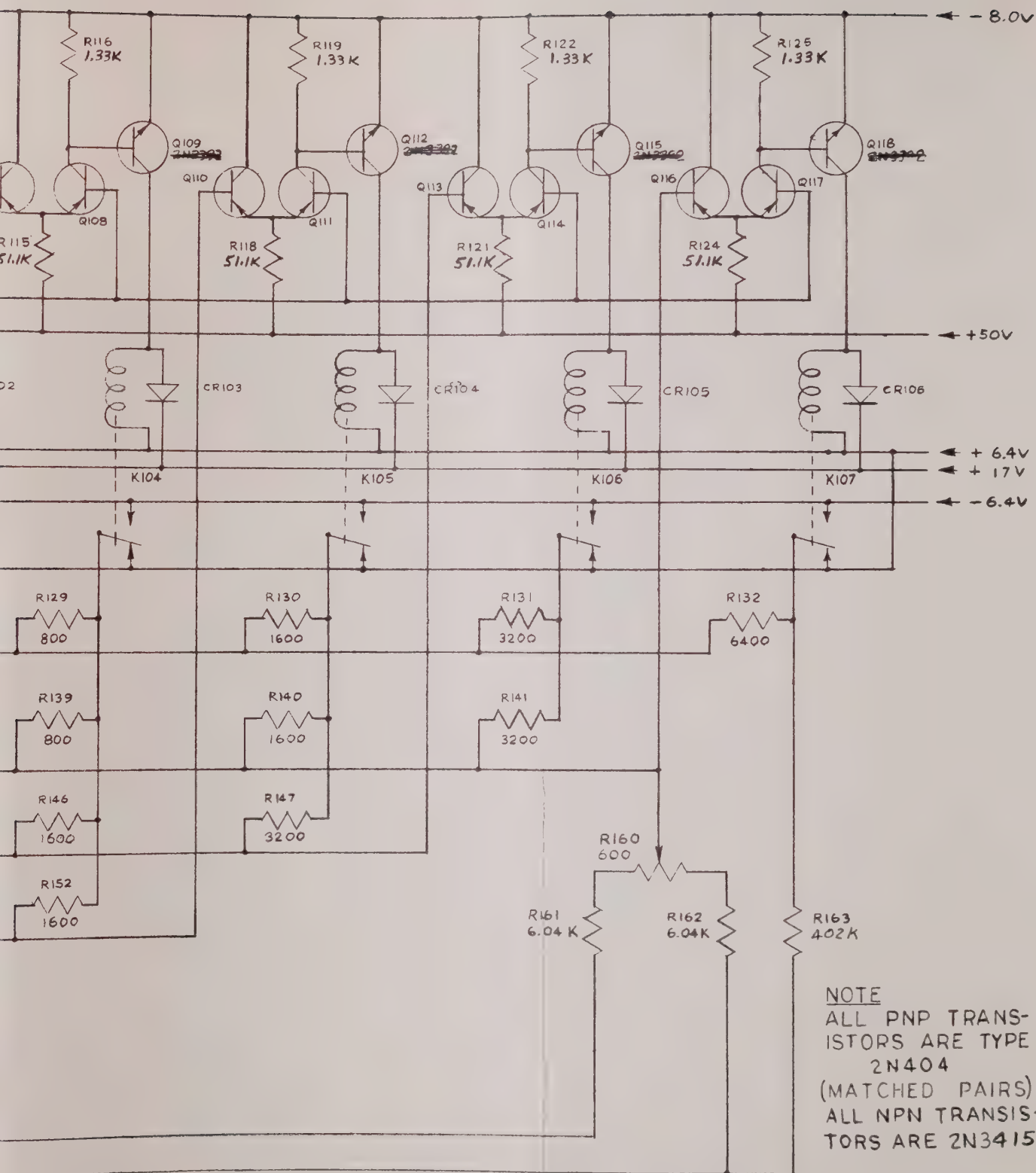




S107

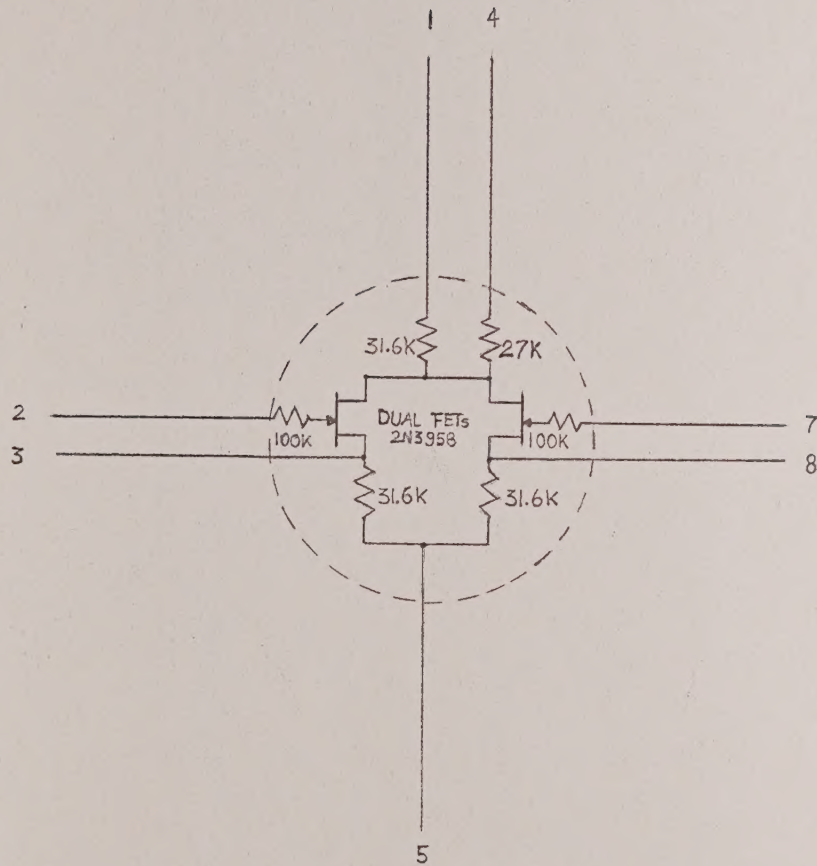
RECORDER  
OPTION









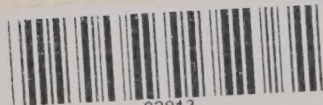


P2003 FET Plug-in Unit  
(interchangeable with P2002)

J-Omega Company  
Mountain View, California







82813